

Negative pressure treatment is also about variation of liquid fluid velocity inside a vacuum kit

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Abstract. Negative pressure treatment is also about variation of liquid fluid velocity inside a vacuum kit. (Abstract).

Aim: The study aims to assess the significance of negative pressure therapy in the treatment of surgical wounds and using the ANSYS simulation software for fluid dynamics calculation will give us the possibility to determine the fluid flow dynamics inside the vacuum kit during its use. **Material and method:** To predict the speed, pressure and temperature of the fluid inside a vacuum kit, we used numerical modeling, using the finite element method, of the gas fluid flow phenomenon. **Results:** The results obtained on the flow velocity - through finite element simulation (FEA) on a model similar to the vacuum kit, demonstrate that the velocity of the liquid fluid, passing through a porous medium, presents significant variations in the upper area of the longitudinal plane xOy, port area and along the suction tube connecting the port to the vacuum pump. **Conclusions:** The mechanical modification of the speed and flow rate of the fluid by introducing a liquid fluid from the outside allows on the one hand the minimization of the surface of the dead zones until they disappear, and on the other hand through the dilution phenomenon it allows the decrease of the bacterial load. These aspects bring arguments for the use of instillation along with the use of intermittent negative pressure to the detriment of the continuous one, thus obtaining mechanical shocks on biofilms.

Keywords : liquid fluid velocity, biofilm, mechanical shocks npwt, wound treatment.

INTRODUCTION

Over time, the products used have become extremely complex and to find solutions to optimize them, such as solving problems of fluid dynamics, systems with moving parts (valves, pistons), where a transient analysis of phase systems is required due to heat exchange (cold / hot) and systems with complex physical phenomena, such as interference between liquids and surfaces requires the use of such computer programs because high quality products can no longer require engineers to rely on the study of phenomena the system is subject, addressing each one separately, but they must be thought of as a unitary whole taking into account in particular the dynamic interaction between them (e.g. the program is used in the conversion of nuclear waste into stable residues, having the ability to accurately predict mixtures required for stabilization).

The ANSYS simulation software for fluid dynamics calculation (CFD) will give us the possibility to determine the fluid flow dynamics inside the vacuum kit during its use. The capabilities of the software product in fluid flow analysis can be used to both design and optimize new devices and to troubleshoot existing negative pressure systems, regardless of the phenomena studied.

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Starting from this study, we aim to analyze the conditions for the development of pressure both inside the sponge and at the contact surfaces between it and the wound, to evaluate the homogeneity and distribution of suction at different set suction values, the flow rate of secretions from the wound to the collecting container, using the polyurethane (PU) sponge.

MATERIAL AND METHOD

The analysis of the flow of liquid fluids through isolated systems demonstrates that the velocity, pressure and temperature of the fluid change continuously. To predict the speed, pressure and temperature of the fluid inside a vacuum kit, we used numerical modeling, using the finite element method, of the gas fluid flow phenomenon.

To solve the problem, we chose the ANSYS - FLUENT program which consists of the solver specialized in fluid flow phenomena.

The three-dimensional geometric model was made using the INVENTOR design program, developed by Autodesk USA. The geometric pattern was assimilated with a porous polyurethane medium, which has an open surface - in contact with the wound, and on the other surface is provided a port that comes into contact with a thin tube with variable geometry.

Discretization of the domain was performed using the unstructured tetrahedral networks from the existing software package in the Fluent solver, according to the rules of good practice in the field. Figure. 1. presents the network of "finite elements" created for the considered model, which contains a number of 159474 nodes, respectively a number of 205093 tetrahedral elements.

The establishment of the limit conditions and the selection of the turbulence model was made according to the lines of good practice, valid in the field.

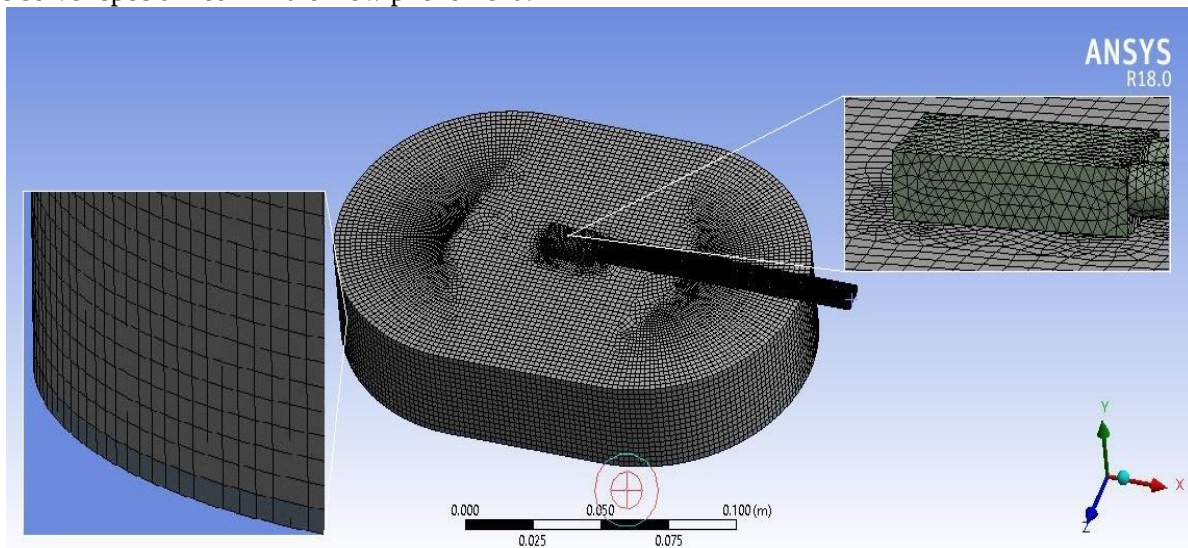
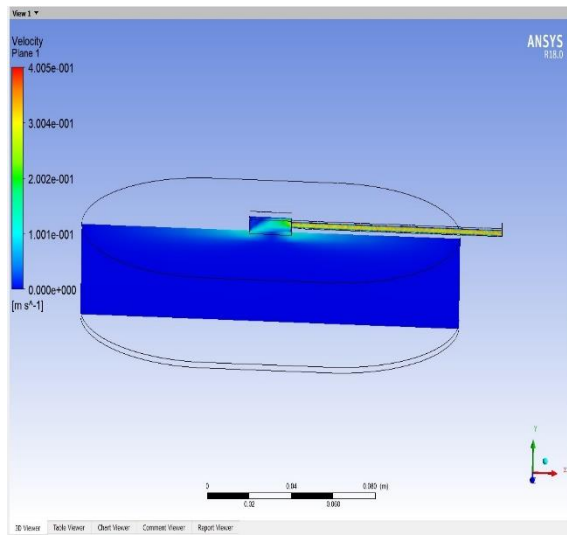


Fig. 1. The discretization network applied to the model.

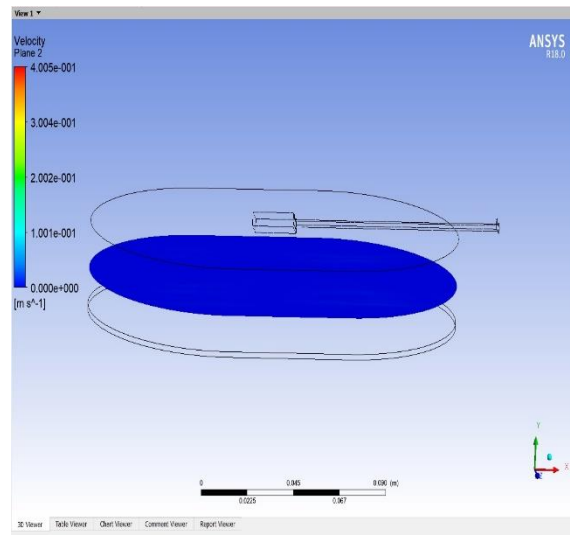
RESULTS

Figure 2 shows the variation of the speed of the fluid volume elements in the xOy

and xOz planes, under conditions imposed by the simulation.

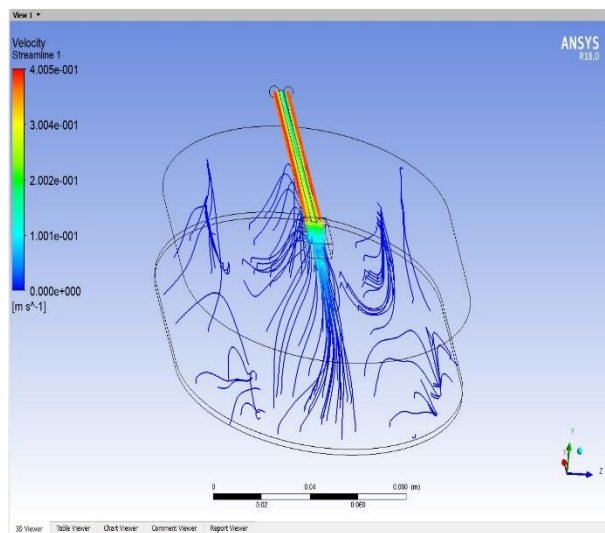


a

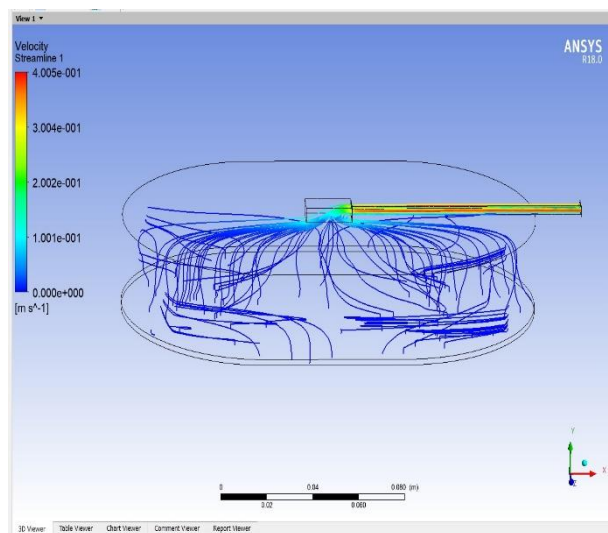


b

Fig. 2. The variation of the speed of the volume elements in: a) the xOy plane; b) the xOz plan.



a.



b.

Fig. 3. Variation of the fluid speed along the current lines inside the model: a) frontal view; b) side view.

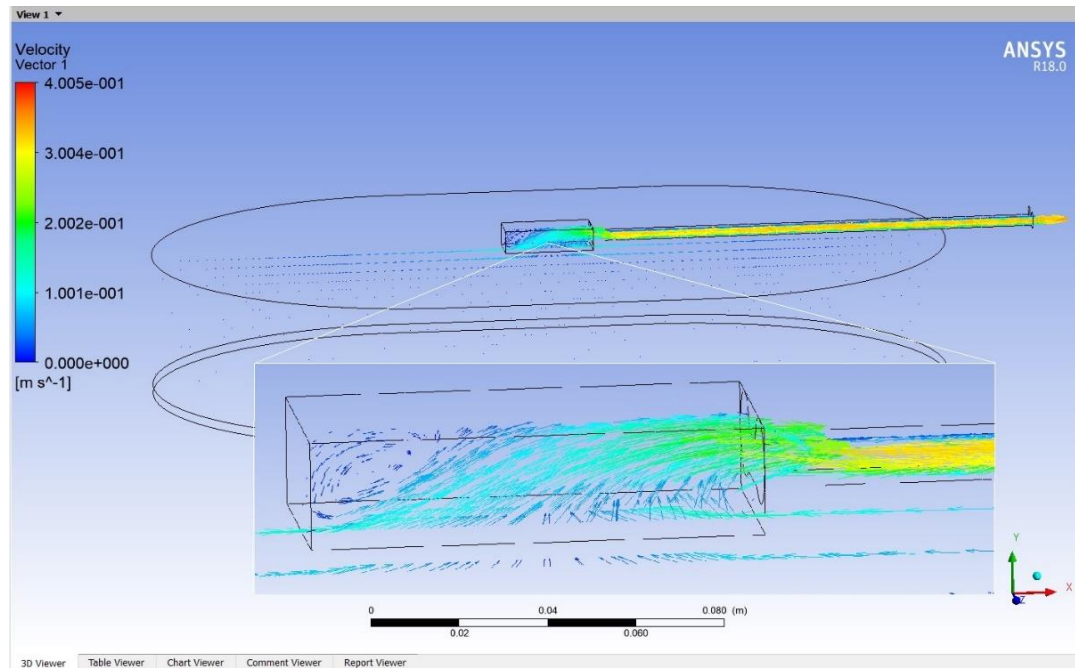


Fig. 4. Distribution of the velocity vector in the xOy plane.

DISCUSSIONS

The results obtained on the flow velocity - through finite element simulation (FEA) on a model similar to the vacuum kit, demonstrate that the velocity of the liquid fluid, passing through a porous medium, presents significant variations in the upper area of the longitudinal plane xOy, port area and along the suction tube that connects the port to the vacuum pump (fig.2. a.).

It can also be observed that the speed of the liquid fluid in the mentioned areas shows an increase of 440% - compared to its value in the lower area -, upon contact of the sponge with the wound. Fig.2.b shows the fact that, in horizontal planes, perpendicular to the xOy plane, the liquid fluid has a constant velocity, except for the planes in the area of the connector port.

Figure 3 shows us that, inside the sponge, the fluid forms streamline along which the velocity varies continuously. It can be noted that,

inside the sponge, the flow regime is continuous, with the exception of the area located inside the connector (fig. 4), where the liquid presents small turbulences, exposed by the variation of the velocity vector, represented in the analysis plane.

The obtained results are closely related to the observations of Kilpadi et al. [1] and Labler et al. [2], who refer to the suction-irrigation process described by Willenegger [3], in which the unidirectional flow of a liquid chooses the shortest path according to the pressure gradient from the inlet port to the suction port and must not confused with instillation therapy. In the irrigation-suction process, it was found that "dead" spaces are created around these irrigation tubes, and these spaces, after several cycles of irrigation-suction, can no longer be washed by the instilled solution, thus determining the persistence of some "septic islands" [4].

There are currently devices that allow the instillation of various substances used in the treatment of wounds, these being programmed at certain, well-defined time intervals. The way in which the substance comes into contact with the wound is the key element in using the adjuvant method in wound treatment. The kits intended for local instillation are composed of multi-orifice catheters, which can be placed at the interface between the sponge and the wound or adjacent to the face of the sponge that comes into contact with the suction port. In the specialized literature we find studies criticizing the use of instillation at the level of the connector, thus determining, at the time of instillation, the pushing of the content retained at the level of the sponge, such as cytokines, bacterial species and activated T lymphocytes back to the level of the wound [Kipaldi et al., 2006; Labler et al., 2006].

The results obtained through the analysis with finite elements, which refer to the connector port, are superimposed on the research results carried out by the companies producing medical equipment, which led to the conception, realization and commercialization of a functional model of the connector port, with a geometry oriented towards a diminish small turbulences, respectively to obtain a continuous flow regime.

Depending on the underlying pathology, chronic wounds and edema are often concurrent, the excess accumulated fluid is accepted as a countervailing healing factor, through the compressive effect it exerts locally on cells and tissues, and thus the supposed increase in tissue perfusion would should determine an improvement of oxygenation at the wound edges. However, De Lange et al. failed to demonstrate any change in tissue oxygenation, using the polarography measurement technique [5].

The results are reinforced by studies carried out by Kamolz et al. Schrank et al., who failed to demonstrate that negative pressure therapy is associated with an increase in tissue perfusion, finding indications that its use brings advantages in the early stages of burn treatment, improved nutrient perfusion, due to the

application of pressure therapy negative being rather the result of the antiedematous effect that promotes perfusion [6,7].

CONCLUSIONS

The velocity of liquid fluid, with properties similar to wound secretions, passing through a vacuum kit made of polyurethane and subjected to negative pressure shows significant variations in the upper area of the longitudinal plane, the port area and along the tube of suction that connects the port to the vacuum pump.

Along the streamlines inside the sponge, the fluid velocity shows continuous variations.

These aspects allow highlighting the fact that inside the sponge the liquid fluid has a transient flow regime that favors the appearance of "dead zones" inside the sponge, characterized by very low and constant fluid flow speeds.

The presence of a low flow rate of the liquid fluid at the sponge-wound interface explains, on the one hand, the reduction of edema at the wound level, and on the other hand, it constitutes an argument in the development of bacterial biofilms.

The mechanical modification of the speed and flow rate of the fluid by introducing a liquid fluid from the outside allows on the one hand to minimize the surface of the dead zones until they disappear, and on the other hand through the dilution phenomenon it allows the decrease of the bacterial load. These aspects bring arguments for the use of instillation along with the use of intermittent negative pressure to the detriment of the continuous one, thus obtaining mechanical shocks on biofilms.

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Conflicts of Interest: The authors declare no conflict of interest.

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